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GEOLOGY OF THE SOUTH HALF OF THE EL TORO QUADRANGLE, ORANGE COUNTY, CALIFORNIA

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CALIFORNIA DIVISION OF MINES AND GEOLOGY

*PREPARED IN COOPERATION WITH THE
COUNTY OF ORANGE DEPARTMENT OF BUILDING AND SAFETY,
ROAD DEPARTMENT AND THE ORANGE COUNTY FLOOD CONTROL DISTRICT.*

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GEOLOGY OF THE SOUTH HALF OF THE EL TORO QUADRANGLE, ORANGE COUNTY, CALIFORNIA

This report is based on work completed in 1970.

By

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1974

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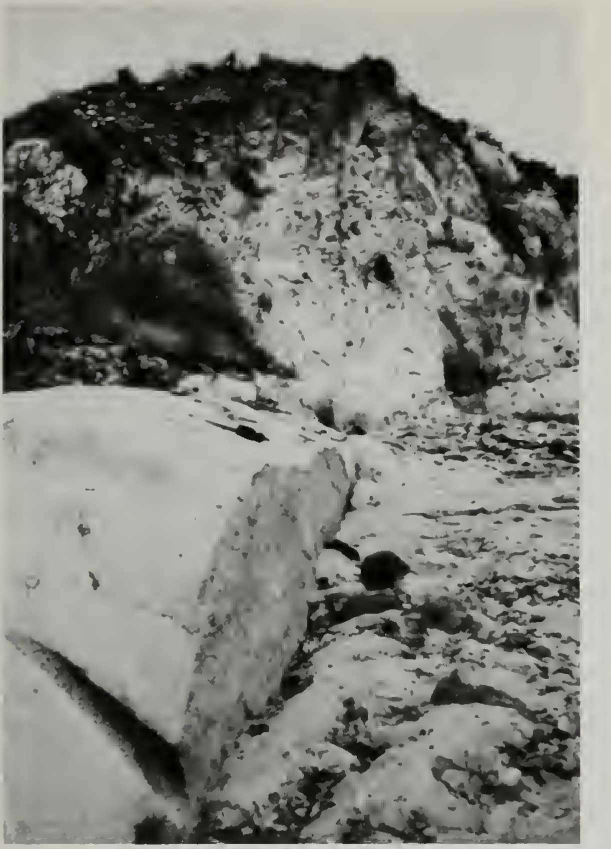

Photo 1. Cristianitos Fault exposed in Aliso Canyon. The stream has differentially eroded sandstone on opposite sides of a shear. Quaternary terrace gravels partially cap an old channel and the fault exposed at the top of the cliff. The sandstone in the foreground looks as if it had been sliced with a knife. (Photo taken after 1969 floods.)

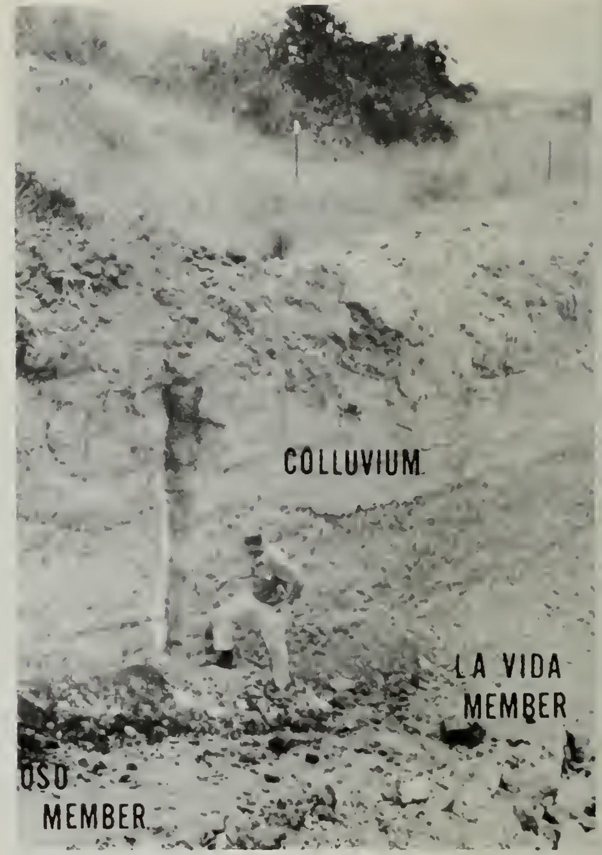

Photo 2. Trench in colluvium exposes the Cristianitos fault contact between the Oso Member of the Capistrano Formation and La Vida Member of the Puente Formation. A single lime filled crack projects up into the colluvium and into the root zone (see pages 9-10). (Photo taken in 1972.)

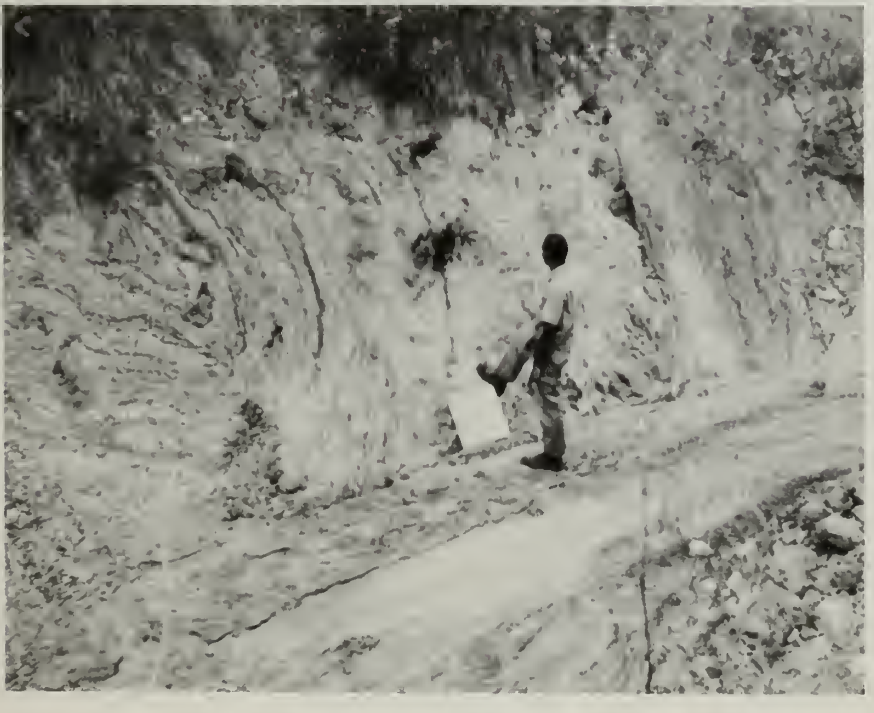

Photo 3. The Cristianitos fault zone exposed in the bottom of Oso Creek. Contorted and vertically tilted diatomaceous and tuffaceous siltstone and shale of the Monterey Formation are exposed on both sides of the fault. (Photo taken after 1969 floods.)

INTRODUCTION

Geography: The south half of the El Toro quadrangle is located approximately 20 miles southeast of Santa Ana, California and includes parts of the rapidly expanding communities of Mission Viejo, El Toro, and Laguna Hills. Most of the area lies on the west flank of the northern Santa Ana Mountains in the Peninsular Ranges geomorphic province and in the transition zone between the Santa Ana Mountains and the Tustin Plain. Elevations range from 200 to 1,500 feet above sea level. Precipitation ranges from 13 to 18 inches per year and usually falls from late autumn through early spring. Temperatures are sufficiently mild for citrus and truck farming.

Three major drainage systems flow south to southwest into the Pacific Ocean. Waters from the south flowing Oso Creek, in the southeast part of the area, reach the ocean 12 miles south near Dana Point. San Diego Creek and its tributaries drain the western portion of the area and empty into upper Newport Bay, nine miles to the west. Aliso Creek flows diagonally across the east-central area from the northeast and passes out of the quadrangle by way of an antecedent course through the San Joaquin Hills, flowing into the ocean ten miles southwest at South Laguna. The importation of water for urbanization, combined with the decline of local pumping for irrigation, has raised water tables to record levels, and many drainages that flowed intermittently, prior to urbanization, now (1972) commonly flow year round.

Purpose: The primary purpose of this report is to provide geologic data and a geologic map in sufficient detail to identify areas of potential or existing geologic problems and hazards. The map is principally designed for general use by geologists, engineers and planners and should not be considered as a substitute for individual site investigation.

Method: Field mapping was done directly on a 1:12,000 enlargement of the U.S. Geological Survey, 1968, 7-1/2 minute, El Toro quadrangle. Stereo black and white 1:24,000 scale aerial photographs taken in 1938 and 1967, and 1:12,000 scale photographs taken in 1970 were used in much of the interpretive study of the geology of the area. Fieldwork was accomplished between December 1968 and December 1969 with minor amounts of work and revisions having been done through February 1972. Mapping by Vedder, Yerkes, and Schoellhamer (1957) was relied upon for bedrock geology. However, numerous new excavations resulted in some re-interpretations and adjustments of geologic map data. The Unified Soil Classification System, as adopted by the U.S. Bureau of Reclamation (see Appendix B) is used in the lithologic descriptions. This classification was only applied, however, to uncemented, weathered or mechanically disintegrated materials. The rippability number assigned to geologic units is in four categories as noted in Appendix C. Color designations used in the lithologic descriptions are taken from the Geological Society of America Rock Color Chart by Goddard and others (1951).

Acknowledgments: This report is a product of a cooperative program of the Orange County Flood Control District, Road Department, Department of Building and Safety, and the California Division of Mines and Geology. Floyd McLellan and Cecil B. Hollon of the Department of Building and Safety were particularly helpful in coordinating and supplying geologic information. Murry Patton of Boyle Engineering, Michael Scullin and James Maniskas of Geolabs, Santa Ana, and Donald Asquith of F. Beach Leighton and Associates, La Habra, facilitated mapping by making available reports and providing access to exploration trenches. Vertebrate fossils were identified by Shelton Applegate of the Los Angeles County Museum, Los Angeles. Takeo Suzuki of the University of California, Los Angeles, identified the invertebrate fauna. Field trips and discussions with J. G. Vedder, R. F. Yerkes, and J. E. Schoellhamer of the U.S. Geological Survey were very helpful in completing some aspects of the investigation. Other persons too numerous to name also gave valuable aid.

GEOLOGIC SETTING

Stratigraphy: Mesozoic crystalline and sedimentary rocks of the Peninsular Range Province underlie the region at depth. In the adjacent Santa Ana Mountains these older, slightly metamorphosed epiclastic and volcanic rocks consist of the Jurassic Bedford Canyon Formation and Santiago Peak Volcanics (Larsen, 1948; Silberling and others, 1961; Fife and others, 1967; Allison, 1970). Both formations are intruded by Cretaceous tonalite and other rocks of the southern California batholith.

Non-conformably overlying these are several thousand feet of Upper Cretaceous sandstone, siltstone and conglomerate of the Trabuco, Ladd and Williams Formations. Upper Cretaceous sedimentary rocks, Jurassic Bedford Canyon Formation and Santiago Peak Volcanics are reported only from petroleum exploration in the south half of the El Toro quadrangle (Vedder, 1970).

Cenozoic rocks are represented by a maximum composite thickness greater than 20,000 feet in the 15 mile wide strip between the Santa Ana Mountains and the coast (Vedder, 1970). The maximum composite thickness exposed in the south half of the El Toro quadrangle is about 5,000 feet.

The oldest rocks exposed in the study area are the late Eocene to early Miocene nonmarine (?) sandstones and conglomerate of the Sespe Formation. The base of the formation is not exposed in the study area, but its thickness exceeds 300 feet. Underlying the Sespe and exposed in adjacent areas is the shallow marine Eocene Santiago Formation.

Overlying the Sespe Formation are 1,500 feet of marine shale, siltstone and sandstone of the lower Miocene Vaqueros Formation. About 500 feet of marine sandstone of the middle Miocene Topanga Formation conformably in turn overlies the Vaqueros Formation. Outside of the area, the Topanga Formation interfingers with the San Onofre Breccia to the west and south and attains a thickness of 7,000 feet north of Laguna Beach (Vedder, 1970). Catalina schist detritus in the sandstone indicates that it was derived, in part, from a source west of the present Pacific coastline (Woodford, 1925).

East of Oso Creek, about 400 feet of the late Miocene marine Monterey Formation unconformably overlies the Topanga Formation. West of Oso Creek, 500 feet of the La Vida Member of the Puente Formation unconformably overlies the Topanga Formation. The lowest part of the La Vida Member is slightly younger than the lowest part of the Monterey

Formation. The units otherwise are equivalent in this area (Smith, 1960) and both are composed of marine siliceous, diatomaceous and tuffaceous shale and siltstone. Conformably overlying the Monterey Formation is an unknown thickness of the marine late Miocene to early Pliocene Capistrano Formation. This unit is principally made up of mudstone on the west and intertongues with the Oso Member to the north and east. The Oso Member attains a maximum thickness of 1,500 feet along Serrano Creek (Vedder, 1957). It is lithologically similar to the Soquel Member of the Puente Formation which conformably overlies the La Vida Member of the Puente Formation. Possibly the Soquel Member and Oso Member are equivalent in the El Toro quadrangle and should be mapped as a single formation. They are, in this study, tentatively mapped as two separate units.

Unconformably overlying the Capistrano Formation are eroded remnants of the marine and nonmarine (?) siltstones and sandstones of the upper Pliocene Niguel Formation. This formation attains a maximum thickness of 300 feet several miles to the south of the area, near the junction of Oso Parkway and the San Diego Freeway.

Structure: The north end of the southeast plunging Capistrano syncline appears to be concealed beneath Quaternary deposits in the central east, and south portions of the quadrangle. This regional structure averages about eight miles in width and occupies the depression between the San Joaquin Hills and the Santa Ana Mountains south of the El Toro quadrangle. The Niguel Formation is found near the center of the structure at the south boundary of the El Toro quadrangle. The recognizable synclinal structure fades out in the vicinity of the El Toro Cemetery. To the south and outside of the study area, the synclinal axis roughly parallels the Atchison, Topeka and Santa Fe railroad tracks south through San Juan Capistrano to Doheney State Beach. The structure controlled location and depths of deposition of the Niguel Formation and many fluvial terrace deposits. It possibly influenced deposition during the late Miocene in the Capistrano embayment of the Los Angeles basin. This embayment probably covered most of the study area and reached depths of about 5,000 feet (Ingle, 1962) during the deposition of the Luisian age Monterey Formation immediately south of the quadrangle in Laguna Hills.

Several faults and folds are found along the flanks of the syncline. In the study area the syncline is covered by undisturbed fluvial and colluvial deposits and alluvial filled channels. In contrast to the undisturbed nature of those deposits within the study area, are the offset Quaternary terraces at Cousteau Park, two miles south of the quadrangle. Miller (1971) describes a seven foot displacement of fossiliferous late Pleistocene age beds along a normal fault.

The most significant fault within the study area is the Cristianitos. It apparently converges with a northwest trending system of frontal faults along the southwest side of the Santa Ana Mountains in the north half of the El Toro quadrangle. A branch of this northwest trending system crosses the northeast corner of the study area where it displaces Sespe, Vaqueros, Topanga, and Puente Formations. South of the El Toro quadrangle the Cristianitos fault can be traced about 20 miles until it enters the ocean near San Onofre Mountain.

The fault is a high angle normal fault striking roughly north-south along the eastern edge of the study area. Within the area, rocks of the Miocene Monterey, Puente and Topanga Formations are exposed on the east side of the fault and rocks of the Puente Formation and the Pliocene Capistrano Formation are generally exposed on the west side. The fault has an estimated normal separation of 1,500 feet, with the east side up, where it crosses Oso Creek. To the south and outside of the study area near Trampas Canyon, Fernandez (1959) estimates a maximum displacement of 4,000 feet. In the study area, the zone of deformation is commonly 500 feet wide with one or two prominent shear zones dipping steeply to the west. Highly deformed units of the Monterey Formation are commonly found in the fault zone and along the edge of the upthrown block. In this area the early Pliocene Oso Member of the Capistrano Formation is the youngest formation displaced by the fault. Holocene (?) stream deposits, 20 feet above the north side of Aliso Creek, have apparently not been disturbed by a west branch of the fault, hence the fault appears to have ceased major activity in this area after the Pliocene and before the deposition of the Holocene (?) terrace deposits. The only evidence suggestive of Holocene activity was seen in a trench excavated in colluvium, where the main branch of the fault crosses Oso Creek. A single lime-filled fissure was found in slopewash on the wall of the trench immediately over a fault contact between the Oso Member of the Capistrano and the La Vida Member of the Puente Formation.

LANDSLIDES AND SLOPE STABILITY

Nearly 400 acres in the south half of the El Toro quadrangle are affected by landslides. Most are in the 4,500 acres underlain by landslide-prone formations in the eastern margin of the area where inherently weak, thinly bedded siltstone and shale are exposed. Slope stability is influenced by a number of interrelated factors and among the more important of these are rock type, moisture retention characteristics, climate, rainfall intensity, relief, erodibility and geologic structure. Alteration of natural slopes by man is particularly important; the diversion of natural drainage, increased moisture content, loading and undercutting of slopes commonly disturb delicately balanced hillside environments. Seismic shaking has also been important but difficult to evaluate because of limited historic documentation.

Most of the larger landslides observed in the study area have been highly altered by erosion and probably can be related to the moist climate during Wisconsin glaciation times. Similar landslides in south Orange County have been dated by radiocarbon methods at 10,000 to 17,000 years before present (Morton and others, in press; Stout, 1969) and quite evidently landsliding was more prevalent in a wetter climate.

Stream erosion is a natural dynamic causative factor in slope failure. In many instances, a landslide or other obstruction on one side of a canyon has diverted drainage patterns so as to undercut the opposite slope, precipitating a slope failure. If the material is homogeneous and not indurated, it tends to fail by flowing or by rotational slumping.

However, most major bedrock landslides in the study area have failed as block-glide landslides (Varnes, 1958) in stratified siltstone and shale. Because of the regional southwest dip in the northeast part of the area, most of these landslides are on southwest facing slopes. On the eastern margin of the area, erosion along the Cristianitos fault has allowed laterally unsupported beds with unfavorable north to west dipping configurations to slide on north to west facing slopes.

Block-glide movement deforms and fractures rock in the landslide mass and because of the fracturing, infiltration of water into the slide mass may be greatly increased. If significant quantities of water are retained, shear strengths are reduced and in addition water loading of the rock material creates an increase in mass weight. Both of these conditions tend to lessen stability and to increase the possibilities for slope distress or failure.

After a slide mass has stopped moving, some loose debris is commonly left high on the slope, creating a potential mudflow hazard. The ground above the slide is, furthermore, usually unstable because of the existence of an oversteepened slide scarp.

These processes were particularly active in the area during the heavy rains of 1938 and 1969. In 1969 numerous slides in the south half of the El Toro quadrangle were reactivated (see dated slides on the geologic map). Mudslides or debris flows issued from loose materials located at the base of several landslides. The loss of debris buttresses in these slides then resulted in several main scarps moving headward due to additional block-gliding.

Within the study area, the most landslide-prone bedrock units, in order of decreasing stability, are the Sespe, Vaqueros, Puente and Monterey Formations. Few landslides were noted to occur in the Niguel, Capistrano or Topanga Formations apparently because of their generally low relief and limited exposure. However, major landslides occur in these formations outside of the south half of the

El Toro quadrangle, particularly in the micaceous siltstone and shale beds of the Capistrano Formation (Blanc and Cleveland, 1969; Edgington, in press).

Siltstone, diatomaceous shale, and tuffaceous shale of the La Vida Member of the Puente Formation and of the Monterey Formation rapidly weather to clay-rich rocks capable of high moisture retention. An increase in moisture content will result in an increase of rock densities in this type of rock material while decreasing shear strength, and eventually failure may occur. These inherently weak rocks are rendered more hazardous by the existence of well developed bedding planes which may serve as incipient shear planes, if bedding dips down and out of the slope.

Creep, slump, and earthflow are characteristic of failures in surficial deposits. Within the area the surficial units in order of decreasing stability are alluvium, fluvial terrace deposits, river terrace deposits, slopewash, and landslide debris. Alluvium and fluvial terrace deposits are usually stable because they are flat-lying and are confined to areas of low relief. Exceptions exist if alluvium or terrace deposits are adjacent to flowing stream or if deposits have been placed on weak landslide-prone bedrock, such as the La Vida Member of the Puente Formation in Aliso Creek. During the 1969 rains, a house in upper Serrano Creek was saved from undermining only by constant bulldozing and backfilling.

Slopewash commonly contains expansive materials as evidenced by polygonal desiccation cracks seen in many parts of the study area during the dry months. These cracks serve to trap water preventing runoff until the material is saturated or until the intensity of precipitation is excessive. Individual foundation sites should be investigated as some expansive slopewash or soil accumulations may cause damaging differential movement of structures. Healed shrinkage cracks can act as hidden planes of weakness which have lower strengths than the surrounding materials. In addition, slopewash materials are often subject to hydro or seismic compaction.

Seepage of subsurface water can create downslope creep, slippage or flow. Springs along fault lines can be particularly hazardous, if large masses of weak and weathered rock become saturated. Several small slides along the Cristianitos fault zone resulted from poor drainage, saturation and plastic flow.

North facing slopes have a slightly greater tendency to accumulate slopewash. Thick accumulations of slopewash and weathered landside debris are commonly perched near the heads of small canyons and present potentials for damaging mud and debris flows. Structures built below these accumulations should be set-back from the slope or otherwise protected. Several persons perished four miles north of the study area during the 1969 storms when a mudflow crushed the upslope wall of a fire station in Silverado Canyon.

The Oso Member of the Capistrano Formation, the La Vida Member of the Puente Formation, and the Monterey Formation are prone to thick slopewash deposition and resultant mudflow during periods of heavy precipitation. Accumulations of thick slopewash are subject to intense rilling and gullying. Debris and mudflows leave only ephemeral scars. Within a year and a half after the 1969 rains, all but the larger scars had disappeared beneath a canopy of vegetation.

In the northeast part of the area resistant sandstone of the Topanga Formation forms bluffs that locally present a rockfall hazard. During the 1969 heavy rains on similar bluffs in the Canyon Acres district of Laguna Beach, boulders were loosened that demolished at least two houses. Debris flows also transported additional boulders from talus accumulations below the bluffs.

A locally hazardous condition is wind erosion of exposed friable Oso and Niguel sandstone beds. Several feet of sand was eroded from newly graded lots near English Canyon and El Toro Reservoir. These friable sandstones are also vulnerable to rilling and gullying from runoff.

Creep is the slow and almost imperceptible downslope movement of soil, slopewash or rock. Within the study area, slopewash and landslide debris are readily affected by creep, particularly during wet seasons. However, if the relief is sufficiently steep, rocks such as siltstone and shale of the Puente and Monterey Formations may be subject to creep or gravity folding, a large scale variety of creep affecting bedded materials. Gravity slide folds occur in similar rocks at depths approximating 100 feet in the Ridge Basin (Fife, 1969) and Stout (1965) reported smaller, but similar gravity folding in the Modelo Formation (=Monterey Formation) near Los Angeles. The largest questionable landslide on the south side of Aliso Creek as well as other questionable landslides may represent creep or gravity folding in progress. This is significant because if the mass is not technically a landslide, it is nonetheless, an inherently unstable rock mass.

Due to the number of geologic variables and the generalizations necessary to cover the study area, each individual site must be examined in detail before development. Site investigations should included evaluations of (1) potential rockfall areas beneath steep slopes, especially in or near the Topanga Formation; (2) areas along active stream channels; (3) sites of rapid erosion in slopewash and landslide debris; (4) control of mud and debris flow or slopewash and landslide debris, particularly on Sespe, Vaqueros, Capistrano, Puente and Monterey Formations; (5) expansibility in thick clay-rich soils and slopewash; (6) creep in slopewash, landslide debris, and weak bedrock; (7) consolidation in slopewash, landslide, and alluvial materials; (8) seepage and zones of weak rock, particularly along the Cristianitos and other fault zones; and (9) slopes with planar structures dipping out of or coincident with the slope, especially in siltstone and shale of the Sespe, Vaqueros, Puente and Monterey Formation.

FAULTS AND SEISMICITY

The 1769 Portola expedition recorded California's first major historic earthquake while camped 16 miles north of El Toro on the Santa Ana River (Richter, 1958). Eleven miles south of the El Toro area, the December 8, 1812 earthquake caused 40 fatalities when the church at Mission San Juan Capistrano collapsed. The destructive 6.3 magnitude, March 10, 1933 "Long Beach" earthquake was centered about 20 miles to the west of El Toro, offshore from south Newport Beach on the probable extension of the Newport-Inglewood fault zone. Wood (1933) estimates a maximum Modified Mercalli Intensity of VI to VII in the El Toro region for the latter event.

In the vicinity of El Toro, the strongest instrumentally recorded earthquake was the May 1938, magnitude 5.5 event centered about ten miles to the east and near upper Trabuco Canyon (California Department of Water Resources, 1964). From 1934 to 1949 the California Institute of Technology (written communication, 1972) reports four additional epicenters of magnitudes 3.5, 3.5, 4.0, and 4.5 also located near the 1938 event. These are possibly associated with continued uplift of the Santa Ana Mountains along the Elsinore fault on the east, and frontal faults on the west.

A magnitude 2 epicenter in Upper Serrano Creek is the only record of seismic activity in the study area between 1934 and 1971 (California Institute of Technology, written communication, 1972).

Historically, the south half of the El Toro quadrangle has experienced seismic shaking from earthquakes that originated on neighboring faults. To the northeast, the San Andreas fault trace cuts within 43 miles of El Toro, the San Jacinto fault within 36 miles, and the Elsinore fault within 14 miles. The Elsinore fault may actually be closer at depth because it appears to be a southwest dipping fault. The Newport-Inglewood fault lies offshore from Laguna Beach, 12 miles to the southwest of the study area. The smaller Norwalk fault lies ten miles northwest of the area.

The 1968, magnitude 6.5 Borrego Mountain earthquake on the San Jacinto fault, created a five percent acceleration of gravity 83 miles from the epicenter on firm sandstone at the San Onofre Nuclear Generating Station (Housner and others,1970) 20 miles south of the study area. In 1971, the 6.4 magnitude San Fernando earthquake, 65 miles northwest of El Toro, created a maximum Modified Mercalli Intensity of VI in the study area (Scott, 1971).

No conclusive evidence of Holocene displacement was found on the Cristianitos fault in the study area. Undisturbed Holocene or earlier terrace deposits cap fault traces in Aliso Canyon, Plano Trabuco, and on the coast at San Onofre Bluff.

A single lime-filled vertical crack in slopewash over the Cristianitos fault trace in a 15 foot trench at the north end of Oso Valley, is believed to have resulted from differential seismic shaking of Oso and La Vida beds on opposite sides of the fault. This may have occurred during any one of the historic earthquakes that were strongly felt locally. The O'Neill Ranch reports (Jack Thompson, oral communication, 1971) a spring on the Cristianitos fault (near the quarter corner of sections 20 and 29, 6S, 7W) started flowing immediately after the March 1933 earthquake. The spring issues from poorly consolidated landslide (?) debris and probably was revived by consolidation or fracturing during seismic shaking.

Stream terraces four miles north of the study area on Santiago Road, between Silverado Canyon and Williams Canyon, have been tilted on end, suggesting that the frontal fault system may have moved during Holocene time in that area. The nearest direct evidence of Holocene faulting was found a mile south of the study area at Cousteau Park. Wade Miller (oral communication, 1971) estimates the age of the displaced terrace deposits as between 30,000 and 100,000 years before present.

During a high intensity earthquake, seismic shaking is the major destructive force. Shaking at a particular locality depends upon many factors some which are distance from the epicenter, and the response of foundation materials. Structures located on thick, poorly consolidated materials commonly suffer greater damage than structures on firm bedrock.

Within the area, deeply weathered bedrock, artificial fill, thick slopewash, alluvium filled canyons, alluvial plains, and landslides should be most susceptible to failure during seismic shaking.

The shallow water table and saturation of loosely consolidated materials may present a liquefaction hazard. Old landslide areas may represent some of the terrain most susceptible to damage or movement from seismic shaking.

D.M. Morton (1971) reported the triggering of many hundreds of landslides during the San Fernando earthquake. The author (Fife, 1969) found many unreported landslides triggered by the 7.7 magnitude 1952 Arvin-Tehachapi earthquake in the Ridge Basin 30 miles south of the epicenter. Many of these were secondary failures in old landslide debris. A similar response should be expected on slopes in the El Toro region.

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APPENDIX A

LITHOLOGY AND ENGINEERING CHARACTERISTICS

Description of Surficial Units

ARTIFICIAL FILL. Quality of fill varies with source of material and method of placement as code requirements. Mostly of local origin, usually semi-pervious to pervious, stable if placed with mechanically controlled compaction, subject to severe rilling and erosion if not properly protected.

(Note: Large areas, obscured and/or covered by man-made cuts and fills, are outlined and labeled as areas of CUT AND FILL.)

ALLUVIUM. (Pleistocene(?) to Holocene)

Lithology: Poorly consolidated, poorly to well sorted, interbedded and crossbedded, white, yellow and olive-gray silt, sand and gravel with frequent cobbly and bouldery sand lenses. Composed mostly of silty-fine-grained sand where derived from Oso Member of Capistrano Formation. Clayey and organic where soil profiles have developed on flood plain in west and northwest portions of area.

Permeability: Moderate to high.

Stability: May stand well in dry cuts, but commonly slumps if saturated.

Rippability: 4; dry clayey materials, 3.

Unified Soil Classification: Principally ML, SM, and SW, with minor GW. Flood plain areas contain Cl and OH horizons.

Remarks: Well data suggests thickness may exceed 200 feet near the runways at El Toro Air Station. In Aliso, Borrego, English, Oso and Serrano drainages the maximum thickness is probably less than 60 feet. It is commonly less than 20 feet thick in San Diego wash.

LANDSLIDE DEBRIS. (Holocene to Pleistocene)

Lithology: Unconsolidated to poorly consolidated debris derived from underlying or adjacent bedrock. Generally landslide deposits are more deeply weathered than surrounding bedrock. Landslides east of the Cristianitos fault zone and those in the northeast corner of the area are commonly derived from diatomaceous and tuffaceous shale and siltstone of the Monterey Formation and the La Vida Member of the Puente Formation.

Permeability: High where open fissures or permeable sandstone beds are involved; lower where siltstone, claystone, and shale make up slide materials.

Rippability: When moist 4 to 3; dry clayey materials, or local unweathered blocks 3.

Stability: Prone to creep, slump, mudflow; especially where loaded by fill or water or where undercut by erosion or excavation. Crown area above slide is commonly over-steepened and prone to further landsliding. Generally subject to consolidation.

Unified Soil Classification: Variable, but commonly ML, CL, and CH.

Remarks: Landslides are typified by poorly drained, hummocky, and subdued topography down-slope from an arcuate crown area marked by an abrupt rise in slope. The toe area commonly obstructs drainage. Active or recently active slides may contain large open fissures and a network of subsurface drainage channels. Maximum depth of some landslides may exceed 100 feet. Suitability for fill varies with source.

Landslides marked by a query (?) are areas where evidence of sliding is not conclusive. In these areas subsurface investigations may be needed to prove or disprove their existance or limits. Dates are noted on landslides where fresh evidence of active sliding was observed. Landslides were classified active if open fissures, fresh scarps, disturbed vegetation, or other ephemeral features indicated new movement.

Landslide deposits are particularly susceptible to shaking and may be reactivated during earthquakes.

SLOPEWASH. (Holocene to Pleistocene(?))

Lithology: Varies with parent materials. In general consists of light olive-gray to olive-gray, silty to clayey, organicly rich soil which is plastic when wet and hard when dry. Consists of detrital materials resulting from debris flows or creep aided by rill wash, ground water, and unchanneled surficial drainage. Accumulates near the base of slopes and at the mouths of small canyons. Includes colluvium and minor residual soils. It is commonly transitional with adjacent soils or alluvial deposits. Mapped where estimated to exceed three feet in thickness.

Permeability: Low to moderate.

Rippability: When moist 4; dry 3.

Stability: Slopewash is particularly susceptible to slump, creep, and debris or mudflows. Commonly it contains expansible clays. Also subject to consolidation.

Unified Soil Classification: Variable proportions of SM, ML, CL, CH, and OH.

Remarks: Generally poorly suited for fills unless blended with coarser materials. Maximum thickness in buried channels is 25 to 35 feet between Serrano and Aliso Creeks in the Oso Member of the Capistrano Formation. Commonly expansive as shown by numerous polygonal desiccation cracks when dry.

RIVER TERRACE DEPOSITS. (Holocene to Pleistocene)

Lithology: Light reddish-brown, poorly to moderately indurated, poorly to well sorted conglomerate. Clast size ranges from one foot boulders to pebbles; average is cobble size; generally rounded to subrounded, composed principally of siliceous metavolcanic and metasedimentary rocks with minor proportion of highly weathered granodiorite to quartz diorite clasts. Matrix of reddish-brown, clayey to silty sand. Redness and induration increase with elevation above stream grade.

Permeability: Low to high, depending on amount of clay in matrix, but generally minor GC.

Stability: Usually flat lying and stable. Caution should be exercised where terraces overlie unstable bedrock, such as on the La Vida Member of the Puente Formation in Aliso Canyon.

Rippability: 3.

Slopewash: Yields cobbly, clayey sand in upper portions of Aliso and Borrego drainages.

Unified Soil Classification: GW, GM, and minor GC.

Remarks: Maximum thickness is less than 100 feet in Borrego Creek. Terrace deposits in English Canyon were used for pervious fill in the construction of El Toro Reservoir (Murray Patton, oral communication, 1969). River terrace deposits are confined to channels and grade laterally into nonmarine terrace deposits that were deposited on a wide flood plain.

NONMARINE FLUVIAL TERRACE DEPOSITS. (Holocene to Pliestocene)

Lithology: Interbedded grayish-yellow to light-brown, thick to thinly bedded, poorly to moderately consolidated, sandy siltstone, clayey sandstone and conglomeratic course-grained sandstone. Buried soil profiles are found locally. Conglomerate clasts are mostly siliceous metavolcanic and metasedimentary rocks. Cobble and pebble proportions increase toward northeastern source areas. Clasts size decreases, roundness and sorting increase from northeast to southwest.

Permeability: Low to high.

Stability: Generally flat-lying and stable.

Rippability: Variable, 4 to 3; dry clayey materials, 3.

Slopewash: Yields typically organic, expansive sandy clay or clayey sand, which locally contains cobbles.

Unified Soil Classification: Principally SW, SM, SC, and CL with minor GM, GC, and ML.

Remarks: Grades laterally into river terrace deposits. Unconformably overlies Niguel, Capistrano, and Monterey Formations. Similar terrace deposits, unconformably overlying the Niguel Formation two miles south of El Toro, contain Late Pleistocene Rancho La Brean age vertebrate fossils, and wood fragments older than 40,000 years B.P. (Miller, 1971). Terrace deposits within the El Toro quadrangle probably have a similar age or at least an age no greater than Late Pleistocene. Thickness probably exceeds 100 feet. Midway between partial section 16 and Serrano Place an excavation for an artificial lake exposed a buried hill of Capistrano Formation (?) 30 feet below the terrace deposits.

Generally makes good pervious to semipervious fill when properly compacted.

Description of Bedrock Units

NIGUEL FORMATION. (Pliocene)

Lithology: Marine and nonmarine (?) yellowish-gray to grayish-yellow-green thick to thinly bedded, well consolidated micaceous siltstone with occasional lenses of poorly sorted crossbedded friable coarse sandstone and conglomeratic sandstone. Clasts are mostly siliceous metavolcanic and metasedimentary rocks from the eastern bedrock complex.

Permeability: Low to moderate.

Rippability: Unweathered 3; weathered zone, 4.

Stability: Generally good on natural slopes, probably because it is usually flat-lying and erodes continuously so that unstable slopes usually cannot form. Cut slopes rill easily.

Slopewash: Yields abundant clayey and sandy silt.

Unified Soil Classification: Principally ML, and SM with minor CL, SP.

Remarks: Unit unconformably overlies Monterey and Capistrano Formations making it difficult to differentiate from Capistrano Formation. The Niguel Formation is slightly less consolidated and commonly contains mammoth crossbeds. Its maximum thickness in the area is about 150 feet. Contains sharks teeth commonly, *Carcharodon megalodon* (Agassiz) 1843, fish vertebrae and the diagnostic Pliocene mollusk *Patinopectin healyi.*

CAPISTRANO FORMATION. (late Miocene to early Pliocene)

Lithology: Marine, yellowish-gray to grayish yellow-green mudstone, siltstone, sandy siltstone, and silty sandstone. Contains numerous coarse to conglomeratic sandstone lenses and local calcareous concretions. Gypsum is common in the weathered zone.

Permeability: Moderate to impermeable.

Rippability: Rippable with convential grading equipment. Weathered zone when moist, 4; unweathered, 3.

Stability: Commonly poor; forms extensive landslides in adjacent areas, particularly in the lower San Juan River drainage (Edgington, in press).

Slopewash: Yields abundant clayey silt and expansive clay.

Unified Soil Classification: Principally CL, and ML with minor SM, and SW.

Remarks: Outcrops limited to southeast corner of quadrangle. Interfingers with Oso Member to the northwest. Thickness in the quadrangle is undetermined, possibly equal to 1,500 foot thickness of Oso Member.

CAPISTRANO FORMATION, OSO MEMBER. (late Miocene to early Pliocene)

Lithology: Marine, white to bluish-white, silty, fine-to medium-grained,thick bedded to massive, poorly sorted arkosic sandstone. Commonly cross-bedded. Locally contains calcareous concretions as much as two feet in diameter. Concretionary zones commonly are found in association with marine vertebrate fossils, but locally friable sand lenses are encountered. Bentonite beds, 1 to 2 inches thick, were observed in an anticline on the east flank of Aliso Creek.

Permeability: High to low

Rippability: 3; minor concretionary zones, 2.

Slopewash: Yields abundant expansive soil and sandy silt, commonly chokes drainages.

Stability: Deep bedrock failures are rare on natural slopes because erosion usually removes weathered bedrock before it becomes a bedrock landslide; however, shallow surficial slides and mudflows are common in wet years. Rills form easily on cut slopes. Friable sand lenses may be unstable if not properly considered in design of artificial cuts and fills. Bentonite, while rare, is expansive and highly plastic; and may cause instability of slopes.

Unified Soil Classification: Principally SP, SW, and SM.

Remarks: Used for pervious fill. In southeast portion of quadrangle, it interfingers with siltstone and mudstone of typical Capistrano Formation. Estimated maximum thickness of this member is 1,500 feet along Serrano Creek (Vedder, 1957). In the north central part of mapped area it probably overlies and interfingers with the Puente Formation. Contains occasional lenses and fragments of marine vertebrates. Many sharks teeth including five inch high *Carcharodon megalodon*, are reported from the borrow pit in Aliso Creek (Schoellhamer, oral communication, 1970).

The Oso Member of the Capistrano Formation may be equivalent to all or part of the Soquel Member of the Puente Formation. Portions of both are Mohnian (Vedder, 1970, oral communication) and one appears to grade laterally into the other. Both are arkosic sandstone. The Oso Member of the Capistrano Formation is generally finer-grained and contains fewer argillaceous lenses than the Soquel Member of the Puente Formation.

PUENTE FORMATION, SOQUEL MEMBER (late Miocene)

Lithology: Marine, interbedded white to pale yellowish-orange, angular to subangular, medium-to coarse-grained, poorly sorted, arkosic sandstone. Usually thick massive beds. Locally contains thick lenses of thinly bedded diatomaceous shale and siltstone similar to those of the La Vida Member of the Puente Formation.

Permeability: Moderate with impermeable lenses of shale. Diatomaceous shale and siltstone have high porosity and may absorb large amounts of water.

Rippability: 3.

Stability: Fair to good on natural slopes. Rills easily on artifical cuts. Interbedded shale and siltstone are unstable and are commonly slide prone.

Slopewash: Sandstone yields small amounts of silt and sand; siltstone-shale yields abundant amounts of silt and expansive clay.

Unified Soil Classification: Principally SW, and SM; with minor ML, and CL.

Remarks: Difficult to distinguish from Oso Sandstone Member of Capistrano Formation. Most distinguishing features are increased angularity and grain-size, and increased occurrence of shale and siltstone interbeds in the Soquel Member. Estimated maximum thickness is 700 feet on the west side of Aliso Creek. Conformably overlies La Vida Member. The Oso Sandstone and the Soquel Member may be equivalent units in the mapped area.

PUENTE FORMATION, LA VIDA MEMBER. (late Miocene)

Lithology: Marine, white to yellowish-gray, well indurated, shale and siltstone. Commonly siliceous with local calcareous concretions. Thin beds and laminations well developed in diatomaceous and tuffaceous shale and siltstone.

Permeability: Low. Diatomaceous and tuffaceous shale and siltstone have high porosity and may absorb large quantities of water.

Rippability: Generally 4 to 3; minor siliciously cemented zones, 2.

Stability: Poor, due to weakness along well developed beddings planes. This unit contains many active landslides. In areas of high relief it may be subject to gravity folding or deep bedrock creep.

Slopewash: Contributes large amounts of expansible clay.

Unified Soil Classification: Principally CL, and ML with minor CH.

Remarks: Occurs only west and north of Oso Creek. Temporally and lithologically equivalent to part of the Monterey Formation. Characteristically contains fish teeth and scales. Estimated maximum thickness is 500 feet along the west side of Aliso Creek. Unconformably (?) overlies the Topanga Formation.

MONTEREY FORMATION. (middle to late Miocene)

Lithology: Marine, white to yellowish-gray, commonly fossiliferous, siliceous shale and siltstone. Locally tuffaceous, porcelaneous and diatomaceous beds, with occasional calcareous and phosphatic concretionary lenses. Thin beds and laminations, well developed in shale and siltstone. Commonly contains 0.5 to 6.0 inch thick layers of unaltered, blue-gray, very well sorted, angular, fine-grained volcanic glass (ash). Physical characteristics similar to the La Vida Member of the Puente Formation. Lowest stratigraphic beds contain coquina limestones northwest of El Toro and south into the San Juan Capistrano quadrangle.

Permeability: Low except for minor sandstone lenses. Diatomaceous lenses have high porosity and may absorb large quantities of water.

Rippability: 4 to 3. Siliceously cemented limestone zones west of El Toro, 1.

Stability: Poor, due to weakness along well developed bedding planes. Commonly forms bedding plane landslides. Unstable adjacent to Cristianitos fault zone because of deformation and low strength of deeply weathered rock. This formation requires special attention in stability analyses of cuts and fills. In areas of high relief it may be subject to gravity folding or deep bedrock creep.

Slopewash: Yields moderate amounts of silt and expansive clay, and siliceous shale fragments; large amounts of expansible slopewash are derived from weathered landslide debris.

Unified Soil Classification: Principally ML, and CL; minor CH.

Remarks: Unconformably overlies the Topanga Formation east of Oso Creek. Estimated maximum thickness of 400 feet east of Oso Creek. In part equivalent temporally and lithologically, to the La Vida Member of the Puente Formation. Oso Creek is an arbitrary boundary between the two units (Vedder and others, 1957). Smith (1960, p. 472) reported middle Miocene (upper Luisian) Foraminifera from the Monterey Formation east of the junction of the geologic section B-B' and the Cristianitos fault. Bryozoan-molluscan limestone 1 to 1.5 miles northwest of El Toro contains the following mollusks: *Saxidomus* sp., *Cardium* sp., *Cerithium* sp., *Pecten* sp., *Pecten* (Lyropecten) *crassicardo* (Conrad), *Saxidomus* cf., *S. nuttalli* (Conrad), *Ostrea* aff. O. *titan eucorrugata* Hertlein and *Ostrea* aff. O. *freudenbergi* Hertlein and Jordan.

Vaquerosella sp., (oral communication, C.W. Allison, and E.C. Wilson, 1970) a small sand dollar, occurs with the bryozoan *V. merriami* (formally Scutella merriami) and constitutes a Miocene (Saucesian to Relizian) index fossil in beds in the San Joaquin Valley of California. Occurrence of *Vaquerosella* sp., in the bryozoan-molluscan limestone is significant because, to the south in the San Juan Capistrano quadrangle, it occurs in limestone and sandstone near the base of the Monterey Formation, and in the upper part of the San Onofre Breccia. The El Toro quadrangle occurrence suggests the limestone outcrops represent the lowest part of the Monterey Formation.

TOPANGA FORMATION. (middle Miocene)

Lithology: Interbedded marine, white to grayish-yellow, calcareous cemented, poorly sorted medium-to coarse-grained arkosic sandstone and conglomeratic sandstone. Clasts are commonly Catalina-type schist derived from the western bedrock complex (Woodford, 1925). Abundant fossiliferous beds and coquina lenses.

Permeability: High to low depending on degree of cementation.

Rippability: 3 to 2; minor calcareously cemented sandstone, 1.

Stability: Usually good. Joints commonly define weakest planar surfaces. In areas of high relief boulders may present a rockfall hazard, especially in wet years or during earthquakes.

Slopewash: Yields small amounts of sand and sandy silt.

Unified Soil Classification: Principally SW, and SP; with minor SM.

Remarks: Contains megafossils such as shark teeth; *Isurus planus* (Agassiz) 1843, *Isurus hastilus* Agassiz 1843, *Carchardon megalodon* (Agassiz) 1843 and *Negaprion* sp.; and mollusks, *Anadara (Scapharca) obispoana* cf. subsp. *obispana* (Conrad) *Ostrea* aff. *O. titan eucorrugata* Hertlein, *Pecten (Lyropecten) crassicardo* (Conrad), *Ostrea aff. O. veptertina loeli* (Hertlein), and *Ostrea* aff. *O. freudenberg:* Hertlein and Jordan and *Pecten* cf. *P. andersoni:* also marine vertebrate skeletal remains including *C. megalodon* vertabrata. Smith (1960) considers the Topanga Formation middle Miocene (Relizian). Estimated maximum thickness in the mapped area is 500 feet on the east side of Oso Creek. The Topanga Formation conformably (?) overlies the Vaqueros Formation in the northeastern and eastern portion of the area.

VAQUEROS FORMATION. (early Miocene)

Lithology: Marine, pale-yellowish-brown to dusky-yellowish-green, moderate to well indurated, interbedded siltstone, sandy siltstone, mudstone, and locally coarse-grained sandstone. Contains local coquina beds and resistant calcareous cemented sandstone.

Permeability: Impermeable to moderately permeable depending on degree of cementation.

Rippability: Weathered zone, 4; unweathered bedrock, 3 ;minor coquina and calcareous sandstone, 2.

Stability: Fair on flat-lying beds. Poor, due to weakness along bedding planes, where beds dip coincident with the slope. Poor unless bedding is flat, then fair.

Slopewash: Yields moderate amounts of clayey and silty sand and minor amounts of bouldery sandy silt and clay.

Unified Soil Classification: Principally ML, and CL with minor SC, and SM.

Remarks: Limited in areal extent in southwest and northeast corners of area. Commonly contains mollusk molds and casts. Estimated maximum thickness in the area is 1,500 feet on the west side of Aliso Creek. Conformably overlies Sespe Formation.

VAQUEROS-SESPE FORMATION, UNDIFFERENTIATED. (late Eocene(?) to early Miocene)

Mapped only in extreme northeast corner of the area.

See description of Vaqueros and Sespe Formations.

SESPE FORMATION. (late Eocene (?) to early Miocene)

Lithology: Nonmarine, moderate-red to very pale orange, thickly bedded, poorly sorted, medium to coarse-grained, clayey arkosic sandstone. Contains minor beds of conglomeratic sandstone and concretionary sandstone.

Permeability: Moderate to impermeable.

Rippability: Weathered zone when moist 4; unweathered 3; concretionary zones 2.

Slopewash: Yields large amounts of expansive, adobe-type clayey sand.

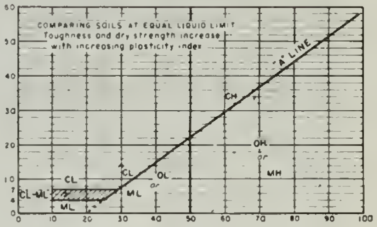
Stability: Fair to poor. Poor due to weakness along bedding planes where beds dip coincident with the slope.

Unified Soil Classification Predominantly SC with minor CL, SW, and SM.

Remarks: Of limited areal extent in southwest corner of area. Relationship with underlying units not shown in area. Estimated thickness is greater than 300 feet in the mapped area. Contains many minor or discontinuous shears disrupting stratification. Identified by enclosed light moderate red mudstone and clayey sandstone.

APPENDIX B

UNIFIED SOIL CLASSIFICATION *(INCLUDING IDENTIFICATION AND DESCRIPTION)*

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 3 inches and basing fractions on estimated weights)						GROUP SYMBOLS [1]	TYPICAL NAMES	INFORMATION REQUIRED FOR DESCRIBING SOILS	LABORATORY CLASSIFICATION CRITERIA			
COARSE GRAINED SOILS More than half of material is larger than No 200 sieve size [2] (The No 200 sieve size is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than No 4 sieve size (For visual classifications, the $\frac{1}{4}$" size may be used as equivalent to the No 4 sieve size)	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes			GW	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name, indicate approximate percentages of sand and gravel, max size, angularity, surface condition, and hardness of the coarse grains, local or geologic name and other pertinent descriptive information, and symbol in parentheses For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics EXAMPLE - Silty sand, gravelly, about 20% hard, angular gravel particles $\frac{1}{2}$-in maximum size, rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength, well compacted and moist in place, alluvial sand, (SM)	Use grain size curve in identifying the fractions as given under field identification	Determine percentages of gravel and sand from grain size curve Depending on percentage of fines (fraction smaller than No 200 sieve size) coarse grained soils are classified as follows - Less than 5% GW, GP, SW, SP. More than 12% GM, GC, SM, SC. 5% to 12% Borderline cases requiring use of dual symbols	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3	
			Predominantly one size or a range of sizes with some intermediate sizes missing			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines				Not meeting all gradation requirements for GW	
		GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)			GM	Silty gravels, poorly graded gravel-sand-silt mixtures				Atterberg limits below "A" line, or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols
			Plastic fines (for identification procedures see CL below)			GC	Clayey gravels, poorly graded gravel-sand-clay mixtures				Atterberg limits above "A" line with PI greater than 7	
	SANDS More than half of coarse fraction is smaller than No 4 sieve size	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes			SW	Well graded sands, gravelly sands, little or no fines				$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3	
			Predominantly one size or a range of sizes with some intermediate sizes missing			SP	Poorly graded sands, gravelly sands, little or no fines				Not meeting all gradation requirements for SW	
		SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)			SM	Silty sands, poorly graded sand-silt mixtures				Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols
			Plastic fines (for identification procedures see CL below)			SC	Clayey sands, poorly graded sand-clay mixtures				Atterberg limits above "A" line with PI greater than 7	
FINE GRAINED SOILS More than half of material is smaller than No 200 sieve size	IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN No 40 SIEVE SIZE											
			DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATANCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)							
	SILTS AND CLAYS Liquid limit less than 50		None to slight	Quick to slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions EXAMPLE - Clayey silt, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML)		 PLASTICITY CHART FOR LABORATORY CLASSIFICATION OF FINE GRAINED SOILS		
			Medium to high	None to very slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays					
			Slight to medium	Slow	Slight	OL	Organic silts and organic silt clays of low plasticity					
	SILTS AND CLAYS Liquid limit greater than 50		Slight to medium	Slow to none	Slight to medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts					
			High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays					
			Medium to high	None to very slow	Slight to medium	OH	Organic clays of medium to high plasticity					
HIGHLY ORGANIC SOILS			Readily identified by color, odor, spongy feel and frequently by fibrous texture			Pt	Peat and other highly organic soils					

[1] Boundary classifications - Soils possessing characteristics of two groups are designated by combinations of group symbols For example GW GC, well graded gravel-sand mixture with clay binder

[2] All sieve sizes on this chart are US standard

FIELD IDENTIFICATION PROCEDURES FOR FINE GRAINED SOILS OR FRACTIONS

These procedures are to be performed on the minus No 40 sieve size particles, approximately $\frac{1}{64}$ in For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests

DILATANCY (Reaction to shaking)

After removing particles larger than No 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch Add enough water if necessary to make the soil soft but not sticky

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction Inorganic silts, such as a typical rock flour, show a moderately quick reaction

DRY STRENGTH (Crushing characteristics)

After removing particles larger than No 40 sieve size, mold a pat of soil to the consistency of putty, adding water if necessary Allow the pat to dry completely by oven, sun, or air drying, and then test its strength by breaking and crumbling between the fingers This strength is a measure of the character and quantity of the colloidal fraction contained in the soil The dry strength increases with increasing plasticity

High dry strength is characteristic for clays of the CH group A typical inorganic silt possesses only very slight dry strength Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen Fine sand feels gritty whereas a typical silt has the smooth feel of flour

TOUGHNESS (Consistency near plastic limit)

After removing particles larger than the No 40 sieve size, a specimen of soil about one-half inch cube in size is molded to the consistency of putty If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch in diameter The thread is then folded and rerolled repeatedly During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line

Highly organic clays have a very weak and spongy feel at the plastic limit

APPENDIX C

SCALE OF RIPPABILITY

1. Very hard to hard. Blasting necessary to probably necessary.
2. Hard to moderately hard. Blasting probably necessary to rippable with difficulty.
3. Moderately hard to firm. Rippable with difficulty to easily ripped.
4. Firm to soft. Easily ripped to easily cut.

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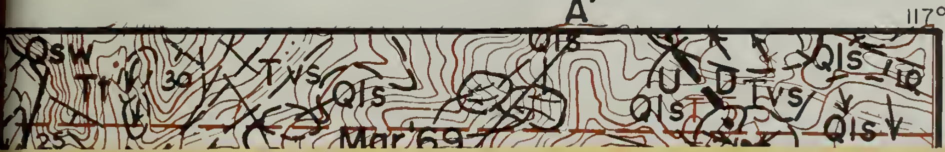
EL TORO QUADRANGLE
SPECIAL REPORT 110 PLATE I

117°37'30"
33°41'15"



STATE DIVISION OF MINES AND GEOLOGY
JAMES E. SLOSSON, STATE GEOLOGIST

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PREPARED IN COOPERATION WITH THE COUNTY OF ORANGE
DEPARTMENT OF BUILDING AND SAFETY, ROAD DEPARTMENT
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TOPOGRAPHIC BASE MAP BY U S GEOLOGICAL SURVEY
This map is enlargement of a
1:24,000 scale published map

GEOLOGY BY DONALD L. FIFE, 1968–1969
REVISED 1972

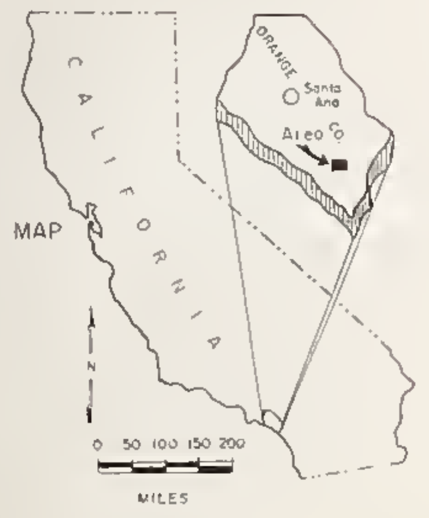
GEOLOGIC MAP AND SECTIONS OF THE SOUTH HALF EL TORO QUADRANGLE, ORANGE COUNTY, CALIFORNIA

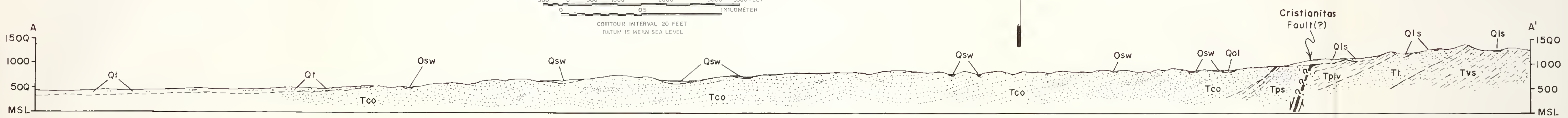
BY DONALD L. FIFE

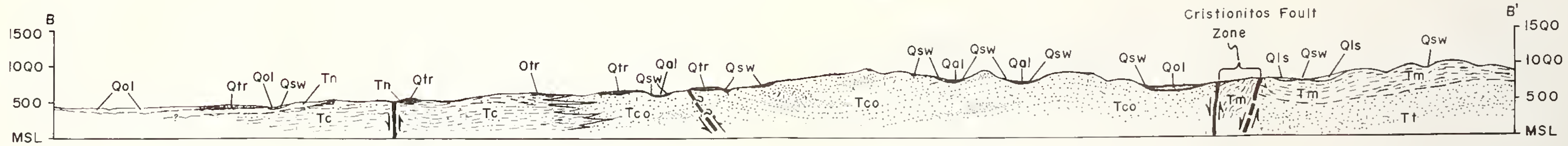
1974

SCALE 1:12,000
0 0.5 1 MILE
500 0 500 1000 2000 3000 3500 FEET
0 0.5 1 KILOMETER
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

INDEX MAP







EXPLANATION

SURFICIAL UNITS

QUATERNARY — Holocene — Pleistocene

Qaf	ARTIFICIAL FILL
Qal	ALLUVIUM
Qsw	SLOPEWASH
Qls	LANDSLIDES
Qtr	RIVER TERRACE DEPOSITS
Qt	NONMARINE TERRACE DEPOSITS

BEDROCK UNITS

TERTIARY — Pliocene — Miocene — Eocene

Tn	NIGUEL FORMATION
Tc	CAPISTRANO FORMATION
Tco	CAPISTRANO FORMATION, OSO MEMBER
Tps	PUENTE FORMATION, SOQUEL MEMBER
Tpst	PUENTE FORMATION, SOQUEL MEMBER, SILT-SHALE BEDS
Tplv	PUENTE FORMATION, LA VIDA MEMBER
Tm	MONTEREY FORMATION
Tt	TOPANGA FORMATION
Tv	VAQUEROS FORMATION
Tvs	VAQUEROS AND SESPE FORMATION UNDIFFERENTIATED
Ts	SESPE FORMATION

SYMBOLS

Contact
Dashed where approximately located; queried where inferred; dotted where concealed

Fault
Dashed where approximately located; queried where inferred; dotted where concealed
U, up thrown side; D, down thrown side. Arrow shows direction and number shows amount of dip on fault plane.

Axis of plunging anticline. Dotted where concealed

Axis of plunging syncline

Strike and dip of beds

Local or approximate strike and dip of beds

Horizontal beds

Strike and dip of joints

Landslide
Arrows show direction of movement

Ephemeral soil, mud or debris flow

water well

Borrow pit or quarry

Cut and fill area
Denotes boundary between natural ground and large excavations and/or artificial fills. Geology from earlier photographs and maps and/or limited outcrops

Spring

Microfossil locality

Megafossil locality

Exploratory hole drilled for petroleum

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